AZOJETE 18 160 II

SEASONAL VARIATION RATES OF DUST FALL AT MOTOR PARKS OF UNIVERSITY OF ILORIN, NIGERIA

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Abstract

The enormous vehicular activities on the commercial motor parks of University of Ilorin, Nigeria called for concern especially as there have been continuous increase of students and other users of the parks. This study was carried out to indicate the seasonal variation in the rate of dust fall at three motor parks in the permanent site of the University campus by using the single bucket sampling method. The study was carried out for five months each of wet and dry season periods. The sampling sites were PK1, PK2 and CI. Gravimetric method was used to quantify the soluble, insoluble, volatile matter and ash. Volatile matter and ash were the component of insoluble dust and the highest rate of insoluble dust deposition was observed in January (2043.12 ± 41.4 and 284.1 ± 35.5 mg/m^2/day) for PK2 and CI and in November (1282.7 ± 64.9 mg/m^2/day) for PK1 when their respective traffic density (1509.5 ±72.1, 29.8 ± 1.2 and 1000.8 ± 48.3 vehicles per hour) was highest. The highest (32713.0 ± 1290.1 mg/m^2/day) and lowest (70.6 ± 6.9 mg/m^2/day) rate of soluble dust deposition in the study were observed at PK1 for September and February respectively which was suspected to be due to increase and decrease in the amount of rain fall. The Pearson Correlation showed that increases in traffic density were correlated with increases in the rate of insoluble dust fall at various sites and the relationship was in the stronger order of PK2 > PK1 > CI. The motor parks ambient air was highly contaminated with soluble dust in the wet season and insoluble dust in the dry season their being values are more than the recommended 133 mg/m^2/day.

Key Words: Insoluble Dust, Soluble Dust, Ash, Volatile Matter, Wet Season, Dry Season.

1. Introduction

Air pollutants can either be particles, liquids or gaseous in nature. Pollutants may come from natural sources or caused by human activities (anthropogenic) such as use of motor vehicles, domestic activities, industry and other economic activities (EPA, 1996; Jimoda, 2012). Particulate matter is used to describe contaminant particles like dust found in the air (Yahi *et al.*, 2014; Nwosu *et al.*, 2016). There could be environmental degradation and hazard on the health status of human and animal due to presence of particulate matter in the air (Kamble, 2015). Particulate matter in the form of dust is usually in the size range from about 1 to 10μm in diameter, and they settle slowly under the influence of gravity. The ones with greater than 10μm that settles to surfaces from the air is the main component of dust fall (Espinosa *et al.*, 2001; Sami *et al.*, 2006; Alahmr *et al.*, 2012) and are too heavy to remain suspended in the air for any period of time. The potential environmental impacts of dust fall were described by Piechota *et al.*, 2002 to include; surface and groundwater quality deterioration, soil contamination, toxicity to soil and water biota. Its toxicity to humans, air pollution and changes in hydrologic characteristics of the soils cannot be over emphasized. A number of medical conditions can be traced to the impact of dust, and the effects of fine wind-borne particles on human health (Garrison *et al.*, 2003, Polizzi *et al.*, 2007, Alahmr *et al.*, 2012). The most health-damaging dust particles are those lesser in size with a diameter than 10 microns (10µ ≤ PM). Chronic exposure to such particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as lung cancer (WHO 2014). Humans mostly at risk are those with symtoms of asthma, influenza lungs, heart, or cardiovascular disease, elderly and children (Kamble, 2015). The presence of dust in the ambient air is very noticeable in the areas where there are more vehicular activities and the composition varies in complex mixture of soluble and insoluble forms of organic and inorganic substances suspended in the air (WHO 2014). The objective of this study is to assess the seasonal variations and traffic effect on the rate of soluble, insoluble, volatile matter, ash and total dust fall at three different parks in the permanent site of the University of Ilorin.

2. Materials and Method

2.1 Study Area

The dust samples were collected at three different motor parks within the permanent site of university of Ilorin, Kwara State, Nigeria. There were two parking locations for commercial vehicles within the campus of the permanent site of University of Ilorin between 2016 and 2017 during the period of this research. The first motor park is located behind Lagos Boys' Hostels of the school, another park; the New Park is by the Sky Chicken restaurant in the permanent site of the University campus. The Clinic Area of the University is about 150 metre away from the location of the New Park and is a parking lot for the clinic staff and their visitors. Figure 1 shows the sampling point locations. Note that none of the parks was paved during the period of the study.

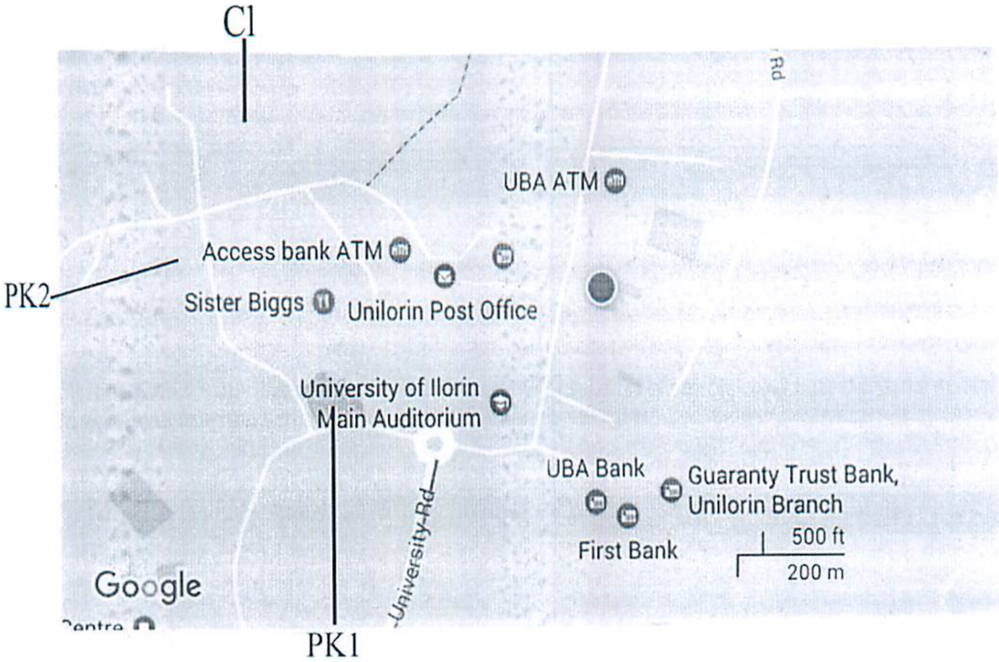

Figure 1: Map of University of Ilorin (permanent site) showing the Clinic and Park locations

The nomenclature of sampling points and description of geographical coordinates are given in Table 1.

Table 1: Description of sampling points and their geographical location.

Sampling Points	Location	Point Coordinates
PK1	First Motor Park	8°47'94.2''N 4°67'06.9''E
PK2	New Motor Park	8°48'13.8''N 4°66'84.0''E
CI	Clinic Area	8°48'27.5''N 4°66'90.3''E

2.2 Sampling Method

The dust fall (bulk type) were sampled using the method of open bucket system according to IS 5182 (2006) and ASTM (2010) standard procedures by using a cylindrical sampling bucket with height (h), radius (r) and surface area (A) of 0.342 m, 0.138 m and 0.05983 m^2 respectively. Several studies (Annegarn and Scorgie, 2002; Moja and Mnisi, 2013; Kamble 2015; Nwosu *et al.,* 2016) have also employed the open bucket method in the past. The exposed buckets were placed on a base plate of a rigid stand comprising of a ring supported by four stabilizing bars above the base plate to prevent the sample from contamination by perching birds. The openings of the buckets were covered with insect net screen so as to only collect dust of smaller size which is most hazardous to health. A known volume of liquid (5L) was placed in the 20 L bucket to trap the dust. The amount of liquid was sufficient to prevent evaporation throughout the sampling period, but not so much for the container to overflow after receiving a normal amount of deposition (IS 5182 (Part 1) (2006). Figure 2 shows one of the rigid sampling stands of 2 m long used for the sampling. The stands were buried into the earth to a depth of about 0.5 m according to some criteria laid by ASTM D 5111 Standards (ASTM, 1996) such as locating the sampler towards the predominant wind direction and considering the distance from obstacles that could interfere in sampling. For sampling collection, the buckets were placed on the rigid sampling stands at the separate sampling sites for a month and the sampling buckets were replaced with new ones of the same dimensions following the same process. The study was carried out for a total of eight months to include five months of rainy season period (September and October, 2016; April to June, 2017) and five months of dry season period (November and December 2016, January toMarch,2017).

\Figure 2: A Sampling Stand at the First Park

2.3 Determination of Insoluble Particle Fall Out Rate

A dried pre-weighed ashless filter paper number 42 was placed in the filter unit according to IS 5182 (Part 1) (2006). The bucket content was then carefully poured through the filtration set up to obtain a filtrate and residue. The residue, an insoluble component of the dust fall, was weighed after drying in an oven at 105°C for 2 hrs. The rate of insoluble dust fall was estimated in duplicate following the method stated by IS 5182 (Part 1) (2006) and Norela *et al.,* (2009) based on number of days and the surface area of the bucket, calculated as in equation (1):

$$C_{idf}((mg/m^2)/day) = \frac{(Mf-Mb)}{AT} \quad \ldots\ldots\ldots(1)$$

Where: C_{idf} = Concentration of Insoluble dust fall ($mg/m^2/day$), Mf = Weight of loaded filter (mg), Mb = Weight of blank filter (mg), A = Surface area of the bucket (m^2), T = Sample duration (days).

2.4 Determination of Total Soluble Particle Fall Out Rate

A known volume of filtrate (soluble matter) was concentrated in a pre-weighed evaporating dish and dried in an oven at 105°C for 2h. It was cooled in a desicator before being weighed. The rate of soluble dust fall was calculated in duplicate using the method stated by Latif and Rozali (1999) as in equation (2):

$$C_{ss}((mg/m^2)/day) = \frac{(M4-M3)\left(\frac{V1}{V2}\right)}{AT} \quad \ldots\ldots\ldots(2)$$

Where: C_{ss} = Concentration of soluble solids, M3 = Weight of evaporating dish without the soluble matter (mg), M4 = Weight of soluble matter with the weight of the evaporating dish (mg), V1 = volume of filtrate (all the water in the sampling bucket) (mL), V2 = Volume of filtrate used for analysis (30 mL), A = Bucket surface area (m^2), T = Sampling period (days).

2.5 Determination of Total Dust Particle Fall Out Rate

This was computed in duplicate by the addition of concentration of the insoluble and soluble dust fall together according to the AQMM (2016) and IS 5182 (Part 1) (2006) as shown in equation (3):

$$\text{TDF } (mg/m^2/day) = C_{idf} + C_{ss} \quad \ldots\ldots\ldots(3)$$

Where: TDF = Total dust fall rate, C_{idf} = Concentration of Insoluble dust fall ($mg/m^2/day$), C_{ss} = Concentration of soluble solids.

2.6 Determination of Ash Particle Fall Out Rate

The mass of ash and volatile particle were determined by incinerating the ashless filter paper containing a known mass of the homogenised dried insoluble matter (one obtained after drying to 105°C) in a pre-weighed porcelain crucible. The porcelain crucible containing the insoluble matter was placed in a muffle furnace at 550 °C for 4 hr. The samples were cooled and weighed until a constant weight was obtained. The amount of ash was determined in duplicate using the equation (4) (Norela *et al.,* 2009):

$$AshRate(mg/m^2/day) = \frac{(Mfa-Mco)N}{AT} \quad \ldots\ldots\ldots(4)$$

Where: Mfa = Weight of porcelain crucible with ash after incineration (mg), Mco = Weight of porcelain crucible only (mg), N= Mf - Mb /x g (Mf - Mb is from equation 1), A= Surface area of the sampling bucket (m^2), T= Sampling period (days).

2.7 *Determination of Volatile Particle Fall Out Rate*

This was estimated in duplicate using equation (5) (Al-Harbi (2015) and Kamble (2015)).

$$VM\ (mg/m^2/day) = C_{idf} - \text{Ash rate} \ \ldots\ldots (5)$$

Where: VM =Volatile matter, C_{idf} = Rate of Insoluble PM in $mg/m^2/day$

2.8 *Quality Assurance and Control*

All the sampling buckets were usually washed thoroughly with soap and water, followed by dilute nitric acid and then deionised water before drying properly. Also, all the sampling apparatus were cleansed by subjecting them to acid wash and then rinse with distilled water before use. Analytical grade stock solutions were used for the preparation of samples and standards.

2.9 *Traffic Density*

The estimation of the traffic entering the park was conducted in duplicate per day (morning and afternoon) during the sampling period of each month and during the periods of heavy traffic throughout the study. The average of these two (morning and afternoon) was the traffic count for a day. The average of the daily counts for each month was used to determine the traffic density for the month (number of vehicles per hour) according to Adekola and Oloruntoba (2000).

2.10 *Meteorological data*

Meteorology data of rain fall, wind speed, humidity and temperature were obtained from the Atmospheric Research Laboratory, Physics department, University of Ilorin, Nigeria.

2.11 *Data Analysis*

A Pearson product-moment correlation coefficient was computed to assess the relationship between the levels of some parameters using the IBM SPSS 20 package.

3. Results and Discussion

3.1 *Traffic Density*

Table 2 shows the average rate of various dust depositions with traffic density at the three sites. The highest traffic density at PK1 was 1000.8 ± 48.3 vehicles per hour in November while the least traffic density at PK1 was 3.0 ± 0.5 vehicles per hour in April. The highest traffic density at PK2 was in January (1509.5 ±72.1vehicles per hour) while the least (43 ± 3.3 vehicles per hour) was in September. The traffic density at CI was highest (29.8 ± 1.2 vehicles per hour) in January while lowest (16.5 ± 0.7) in September. The least value of traffic density in this study was observed in April (3 ± 0.5 vehicles per hour) at PK1 during the period of inter-semester break and when it was not really active as Motor Park. Though, the school resumed in October, it seemed most students and staff resumed fully to school or more visitors entered into the school campus in January. This accounted for the highest traffic density in this study to be in January (1509.5 ±72.1vehicles per hour) at PK2. Also PK2 was the most active park during this January period. Nwosu *et al.*, (2016) reported a similar observation on a motor park in the same University.

Table 2: Average and Standard Deviation of Soluble, Insoluble, Ash, Volatile and Total Dust Fall in mg/m^2/day with Traffic Density (Number of vehicles per hour) (n = 2).

Month	Sample	Insoluble	Soluble	Ash	Volatile Matter	Total Dust Fall	Traffic Density
Sep	PK_1	340.8 ± 3	32713.03 ± 1290	94.4 ± 1.4	246.1 ± 4.3	33053.5 ± 1287	305 ± 22.6
	PK_2	208.9 ± 0	27579.6 ± 732	82.7 ± 1.2	126.2 ± 1.2	27788.5 ± 732	43 ± 3.3
	CI	154.6 ± 5.9	19706.2 ± 442	116.3 ± 3.9	38.3 ± 2.0	19860.8 ± 448	16.5 ± 0.7
Oct	PK_1	355.1 ± 5.9	18094.8± 928	124.4 ± 14.6	230 ± 8.7	18094.8 ± 928	387.8± 22.4
	PK_2	305.4 ± 6.5	17012.1 ± 666	136.1 ± 17.03	169 ± 23.5	17317.5 ± 672	51.2 ±2.1
	CI	213.1 ± 5.9	13780.4 ± 826	170.1 ± 15.5	43 ± 9.6	13993.5 ± 8	18.3 ±0.9
Nov	PK_1	1282.7 ± 64.9	4671.5 ± 454	690.1± 16.8	592.6 ± 48.1	5954.2 ± 389	1000.8 ± 48.3
	PK_2	630.9 ± 17.7	1848.5 ± 102	503.7 ± 66.4	127.2 ± 48.7	2479.4 ± 120	58.5 ±3.1
	CI	238.6 ± 29.5	1314.4 ± 199	179.4 ± 29.4	58.8 ± 0.3	1552.5 ± 228	25.7 ± 1.9
Dec	PK_1	129.5 ± 5.9	2372.3 ± 466	40.9 ± 4.6	88.7 ± 1.3	2501.8 ± 460	3.5 ± 0.7
	PK_2	2013.9 ± 118.2	891.1 ± 31.2	431.02 ± 27.2	1582.8 ± 91	2905 ± 87	1428.7 ± 388
	CI	309.2 ± 11.8	727.7 ± 26.6	227.7 ± 16.3	81.5 ± 4.5	1036.84 ± 14.8	25.8 ± 2.6
Jan	PK_1	259.0 ± 11.8	825.9 ± 33.2	213.5 ± 11.7	45.5 ± 0.1	1085 ± 21.4	5.3 ± 0.9
	PK_2	2043.1 ± 41.1	1247.3 ± 39.5	1865.8 ± 30.4	177.3 ± 11	3290.4 ±1.9	1509.5 ±72.1
	CI	284.1 ± 35.5	983.5 ± 12.1	266.2 ± 34.5	17.9 ± 0.9	1267.6 ± 47.6	29.8 ± 1.2
Feb	PK_1	254.9 ±29.5	70.6 ± 6.9	179.8 ±21.1	75.0 ± 8.5	325.5 ± 22.7	4.3 ± 0.9
	PK_2	1654.6 ±23.6	134.9 ±15.6	363.3 ±10.3	1291.2 ± 13.4	1789.1 ± 8	1506 ±144.2
	CI	267.4 ±11.8	281.5 ± 25.7	192.3 ± 9.9	75.1 ± 1.9	548.9 ± 13.8	29.7 ± 2.8
Mar	PK_1	208.9 ± 11.8	297.5 ± 41.4	88.6 ± 2.4	120.3 ± 14.2	506.4 ± 29.5	3.8 ± 0.2
	PK_2	1261.8 ± 11.8	500.6 ± 15.3	554.6 ± 1	707.2 ± 10.8	1762.4 ± 3.5	930 ± 59.4
	CI	263.2 ± 5.9	446.4 ± 10.8	115.8 ± 0.12	147.4 ± 5.79	709.6 ± 4.92	21.8 ± 1.2
Apr	PK_1	254.9 ± 5.9	502.6 ± 1.4	76.4 ± 4.8	178.5 ± 10.7	757.5 ± 4.6	3 ± 0.5
	PK_2	292.5 ± 11.8	886.0 ± 64.6	104.7 ± 1.5	187.8 ± 13.3	1178.5 ± 52.8	528 ± 169.7
	CI	288.3 ± 5.9	690.4 ± 9.7	170.1 ± 0.6	118.2 ± 6.5	978.7 ± 3.8	17 ± 1.9
May	PK_1	167.1 ± 11.8	4129.4 ±382	60.5 ± 8.2	106.6 ± 3.6	4296.5 ± 370.2	3.7 ± 0.9
	PK_2	259.0 ± 11.7	2541.6 ±10.0	239.7 ± 16.4	19.3 ± 4.6	2800.6 ± 21.9	1164 ± 67.9
	CI	228.1 ± 3.6	2219.2 ±208	189.3 ± 0.3	38.8 ± 3.8	2447.3± 211.9	26.3 ± 0.9
Jun	PK_1	271.6 ± 17.7	3416.3 ± 364	68.0 ± 8.9	203.5 ± 8.9	3687.8 ± 381	992 ± 18.4
	PK_2	196.4 ± 17.7	3326.1 ± 174	37.4 ± 0.9	158.9 ± 16.9	3522.5 ± 156.7	1057.5 ± 31.8
	CI	346.8 ± 17.7	3813.5 ± 299	154.8 ± 21.3	191.9 ± 3.6	4160.3 ± 281	24.5 ± 0.7

(±) standard deviation

3.2 *Insoluble, Soluble Dust and Traffic Density*

The lowest insoluble dust was observed at PK1 in the month of December (129.5 ± 5.9 mg/m^2/day) which could be due to low traffic density (3.5 ± 0.7 vehicles per hour) observed at this park during the month. The highest (2043.12 ± 41.4 mg/m^2/day) insoluble dust was observed at PK2 for the month of January which may be attributed to the highest traffic density (1509.5 ±72.1vehicles per hour) observed at the park in that month. The highest insoluble dust was observed in January (2043.12 ± 41.4 and 284.1 ± 35.5 mg/m^2/day) for PK2 and CI respectively; PK1 in November (1282.7 ± 64.9 mg/m^2/day) when their respective traffic density (1509.5 ±72.1, 29.8 ± 1.2 and 1000.8 ± 48.3 vehicles per hour) was highest. The same observation was reported by Khan *et al.*, (2002), Norela Khan *et al.*, (2013), *et al.*,(2009), Malokootia *et al.*, (2013), Tyagi *et al.*, (2014) and Nwosu *et al.*, (2016)in their separate studies. That is, the rate of insoluble dust deposition increased as the traffic density increased. This means that movement of vehicles and passengers are key factors in the generation of insoluble dust. The soluble dust had no regular pattern of relationship with the traffic density. Thus, some other factors may be responsible for its deposition.

3.3 Ash Matter, Volatile Matter and Traffic Density

Generally, the highest (1865.8 ± 30.4 mg/m^2/day) ash matter was observed at PK2 for January and the lowest (40.9 ± 4.6 mg/m^2/day) was obtained at PK1 for December. The traffic density was highest (1509.5 ±72.1vehicles per hour) at PK2 in the month of January. Also, PK1 which had the lowest ash in December had a very low traffic density (3.5 ± 0.7 1vehicles per hour). Thus, it seemed that the major cause of the ash component is dependent on the traffic activities. During the period of this study, the highest (1582.8 ± 91 mg/m^2/day) volatile matter was observed at PK2 for December which was not the month of its highest traffic density. Volatile matter was lowest (17.9 ± 0.9 mg/m^2/day) for January at CI when it had its highest traffic density as 29.8 ± 1.2 vehicles per hour. This seemed that volatile matter did not necessarily depend on the traffic density. That is, vehicular activities were likely not the major cause of volatile matter but probably the combustion of oil, refuse and tiny decaying leaves shed from the trees around the areas of study (Kamble 2015).

3.4 Dust fall at various sampling points

According to Table 2,the soluble dust generally decreased monthly from September to February and increased from March to May at all the sampling points such that the highest (32713.0 ± 1290.1 mg/m^2/day) and lowest (70.6 ± 6.9mg/m^2/day) soluble dust in the study were observed at PK1 for September and February respectively. The decrease in the soluble dust must be due to decrease in the amount of rain fall from September to February while the increase must be due to increase in rain fall and precipitation from March to May. This was in line with the findings of Norela *et al.*, (2009) and Kamble (2015) who said that the soluble dust was always more than the insoluble dust in the wet season. Therefore, the major cause of the soluble dust may be components of aerosols which are usually washed down from the atmosphere in larger quantity by rain during wet seasons.

On the other hand, the insoluble dust increased from September to January and decreased from February to May for PK2 and CI. At PK1, the insoluble dust increased from September to November before the park became inactive in December. The increase in the insoluble dust was likely due to decrease in the amount of rain fall from September to January. AL-Harb (2015) reported that insoluble dust increases as the rain fall decreases. This is because when there is no heavy rain fall to wet the ground and wash away the top soil, the traffic activities would be able to lift more dust into the atmosphere.

3.5 Seasonal Comparison of the three sampling points and other studies

The average rate of parameters of each season was obtained by taking the average of monthly concentrations for each season. Table 3 presents seasonal comparison of average insoluble, soluble, volatile, ash and total dust fall.

3.5.1 Wet Season

The results in Table 3 for wet season shows that rate of soluble dust was highest (11771.2mg/m^2/day) at PK1 followed by PK2 (10269.1mg/m^2/day) and then CI (8041.9mg/m^2/day). There was probably high amount of soluble particles in the suspended particulate that was washed down by rain fall at PK1 than PK2 and CI. The observed amount for the rate of soluble dust in the present study at all the sampling sites during the wet season period was higher than observed by Norela *et al.*, (2009) (216.11 mg/m^2/day) and Alahmr *et al.*, (2012) (78.41 mg/m^2/day). This may be because the study of Norela was at a residential area and that of Alahmr *et al.(2012)* was at a Semi-Urban Area both of which have less amount of soluble aerosol or suspended particulate matter washed down by the rain fall or the rain falls were not heavy enough to wash down the suspended matter. The insoluble dust at all sampling points were very close in the wet season with PK1 having the highest (277.9mg/m^2/day), followed by PK2 (252.4 mg/m^2/day) and then Cl (246.2 mg/m^2/day). The insoluble dust at all the sampling points in this present study during the period of wet season were more than that of Norela *et al.,* (2009) (37.83 mg/m^2/day) and Alahmr *et al.,* (2012) (53.08 mg/m^2/day). This may be attributed to the two studies conducted in areas of less traffic densities and low generation of dust.

Table 3: Seasonal Comparison of Average Insoluble, Soluble, Ash, Volatile and Total Dust fall (mg/m^2/day) in this study and previous studies

Study	Research Site Area	Season	Traffic Density	Soluble	Insoluble	Volatile Matter	Ash	Total Dust Fall	DOE, 2005
This study,PK1	Motor Park	Wet Season	338.3 hr^{-1}	11771.2	277.9	193.1	84.7	12049.1	133
		Dry Season	203.5 hr^{-1}	1647.6	427	184.4	242.6	2074.6	
This study,PK2	Motor Park	Wet Season	568.7 hr^{-1}	10269.1	252.4	132.3	144.4	10521.5	
		Hot Season	1086.5 hr^{-1}	924.5	1520.8	543.2	974	2445.3	
This study,Cl	Motor Park	Wet Season	20.5 hr^{-1}	8041.9	246.2	85.3	167.6	8288.1	
		Dry Season	26.6 hr^{-1}	750.7	272.4	76.1	196.3	1023.1	
Nwosu et al., (2016)	Unilorin Motor Park	Dry Season	300day^{-1}	*	1122.2	*	*	*	
	Kwasu Motor Park	Dry Season	103.2 day^{-1}	*	627.7	*	*	*	
	Unibadan Motor Park	Dry Season	273.4 day^{-1}	*	316.3	*	*	*	
Alahmr*et al.,* (2012)	Semi-Urban Area (Kajang and Bangi, Malaysia)	Wet Season	*	78.41	53.08	*	*	131.50	
Norela *et al.,* (2009)	Residential Area (Negeri Malaysia)	Wet Season	*	216.11	37.83	*	106.96	253.95	
Al-Harbi, 2015	Urban area, (Shuwaikh, Kuwait)	Dry Season	*	*	*	*	944.23	*	

(*) Not available

The total dust fall at PK1 was highest (12049.1 mg/m^2/day) followed by PK2 (10521.5 mg/m^2/day) and then Cl (8288.1 mg/m^2/day) according to Table 3. That means the rate of dust deposition at PK1 was higher than PK2 and Cl in the wet season period. The observed amounts of total dust fall in this study at all the sampling stations were higher than observed by Norela *et al.,* (2009) (253.95 mg/m^2/day) and Alahmr *et al.,* (2012) (131.50 mg/m^2/day). This may be because the study of Norela was at a residential area and that of Alahmr was at a Semi-Urban Area, both of which may have lesser amount of settling dust. The volatile matter component was highest (193.1mg/m^2/day) at PK1 followed by PK2 (132.3 mg/m^2/day) and then Cl (85.2mg/m^2/day) in the wet season. Volatile was higher than ash in the months of the wet season while low in the months of the dry season for PK1. It was probably because PK1 had been a motor park quite a time before this study. Rainfalls could have washed down suspended matter generated as a result of combustion of oil, refuse and tiny decaying leaves shed from the trees around the area. The volatile matter was higher than ash in the months of the wet season for PK1. The ash matter in the wet season as presented in Table 6 shows highest value (167.5mg/m^2/day) at Cl followed by PK2 (144.4 mg/m^2/day) and PK1 (84.7mg/m^2/day). This high value at Cl could mean that the top sandy soil at Cl was rich in soil mineral than in PK1 and PK2 areas in the wet season period. The top soil could be blown up by rainy season wind to become settling dust. All the values obtained for ash in this study during wet season period were higher than (106.96mg/m^2/day) obtained by Norela *et al.*, (2009).

3.5.2 Dry Season

Table 3 also presents the results obtained in the dry season period. Soluble component was highest (1647.6 mg/m^2/day) at PK1 followed by PK2 (924.4mg/m^2/day) and then Cl (750.7mg/m^2/day). The highest value at PK1 could be as a result of deposition of soluble particles lifted from the ground. The insoluble component was highest (1520.8mg/m^2/day) at PK2 followed by PK1 (427mg/m^2/day) and then Cl (272.4mg/m^2/day) in the dry season as presented on Table 3. This must have resulted from their respective obtained traffic density (1086.5, 203.5, 26.6 vehicles per hour) in the season. The insoluble dust obtained for PK2 in the dry season of this present study was more (1743.3mg/m^2/day) than that obtained by Nwosu *et al.*, (2016) (1122.2 mg/m^2/day) at a motor park in the same university environment. The higher average traffic density (1086.5 vehicles per hour) observed for dry season at PK2 during this present study compared to that of Nwosu *et al.*, (2016) (300, 103.2 and 273.4 vehicles per day) in the same dry season must have contributed to the increase in the insoluble dust. Total dust fall at PK2 was the highest (2445.3mg/m^2/day) followed by PK1 (2074.5mg/m^2/day) and then Cl (1023.1 mg/m^2/day) in the dry season. The high traffic density (1086.5 hr^{-1}) and hauling movement of people on the dry unpaved area of land at PK2 must have greatly contributed to this high value. Volatile matter component was highest at PK2 (543.2 mg/m^2/day) followed by PK1 (184.4 mg/m^2/day) and then Cl (76.1mg/m^2/day) in the dry season as shown in Table 3. The soil around PK2 could contain more of volatile dust than other sites in this study. It might be because it was formerly a grass land before it was recently adopted as a motor park. Therefore, it was easier for traffic activities and hauling movement of people to have contributed to lifting of soil reach in organic matter in the area. The ash matter component presented on Table 6 was highest (974 mg/m^2/day) at PK2 followed by PK1 (242.5mg/m^2/day) and Cl (196.3mg/m^2/day) in the dry season. That is the insoluble dust collected at PK2 during the dry season contains more of ash than Cl which has the highest in the rainy season. Also, ash component at PK2 in the dry season was more than that obtained (944.23 mg/m^2/day) by Al-Harbi, 2015 in an urban area of his study.

3.5.3 Comparison between Dry and Wet Seasons

Figures 4-6 show the seasonal comparison of dust fall and components at all sampling sites. It was observed that at all the sampling points in this study; the total dust in the wet season period was more than that in the dry season period which could be attributed to the washing down of more suspended particulate matter in the rainy season than dry season. According to Alahmr *et al.*, (2012), wet deposition is the main process which brings down particles from the air. Soluble component obtained during the wet season period was found to be more than that of the dry season period. That is, rain fall do contribute to the washing of the atmosphere thereby depositing aerosol and other particulate matter most of which are probably dissolved in water. Chate and Pranesha (2004) reported that heavy rain could capture aerosol particles and wash it down from the atmosphere. The insoluble matter was lower in the wet season period than in the dry at all the sampling points. Glavas *et al.,* (2008) and Al-Harbi (2015) reported that heavy rain fall causes wetting of the ground and wearing away of the top soil which cause reduction in insoluble matter during wet season. That is, insoluble dust increases from wet season period to the dry season period.

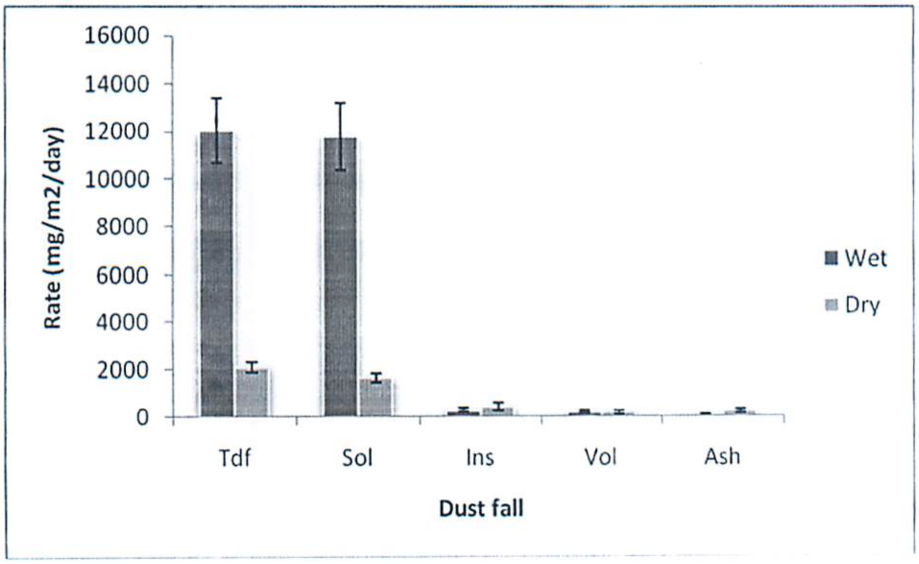

Figure 4: Seasonal Comparison of Total Dust Fall and Components at PK1 (Tdf = total dust fall, Sol = soluble dust, Ins = insoluble dust, Vol = volatile matter and Ash)

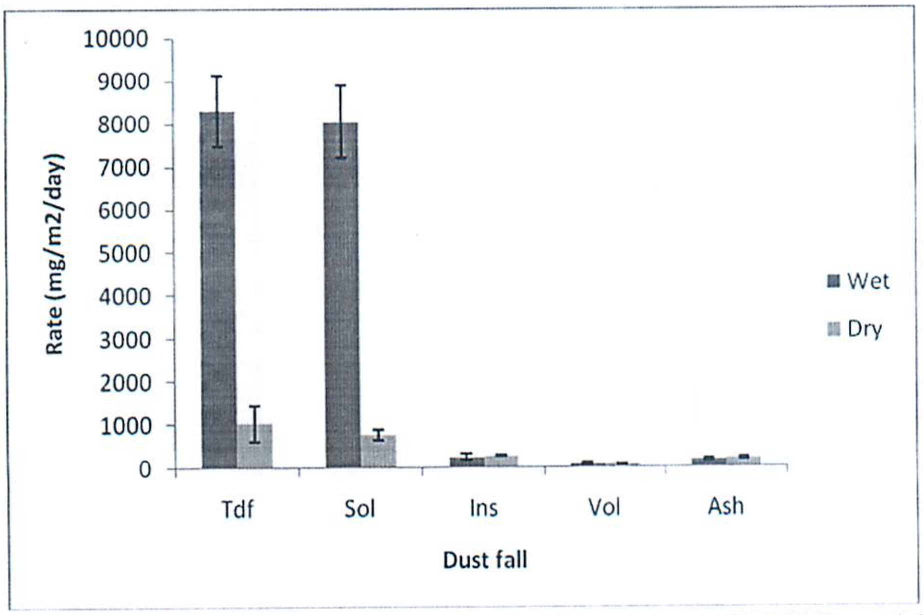

Figure 5: Seasonal Comparison of Total Dust Fall and Components at PK2 (Tdf = total dust fall, Sol = soluble dust, Ins = insoluble dust, Vol = volatile matter and Ash)

This is according to the findings of Manahan (2001), Kamble (2015) and Ifeanyi *et al.*, (2016) that reported dust fall increases during the dry season because of low humidity conditions which enables easy lifting of dry soil by hauling movement and traffic activities. Volatile matter was lower in wet season period than in the dry season period at PK2, while the opposite was the case at PK1 and Cl. Rainfalls could have washed down suspended matter generated as a result of combustion of oil, refuse and tiny decaying leaves shed from the trees around the PK1 and Cl. Kamble (2015) also observed that increase in volatile matter may be from combustion of oil, coal or refuse. Ash matter was also lower in wet season period than in dry season period at all the sampling points. The observation suggested that the surface dust found around all the sampling points may be rich in minerals which have been blown into the container by traffic and wind activities.

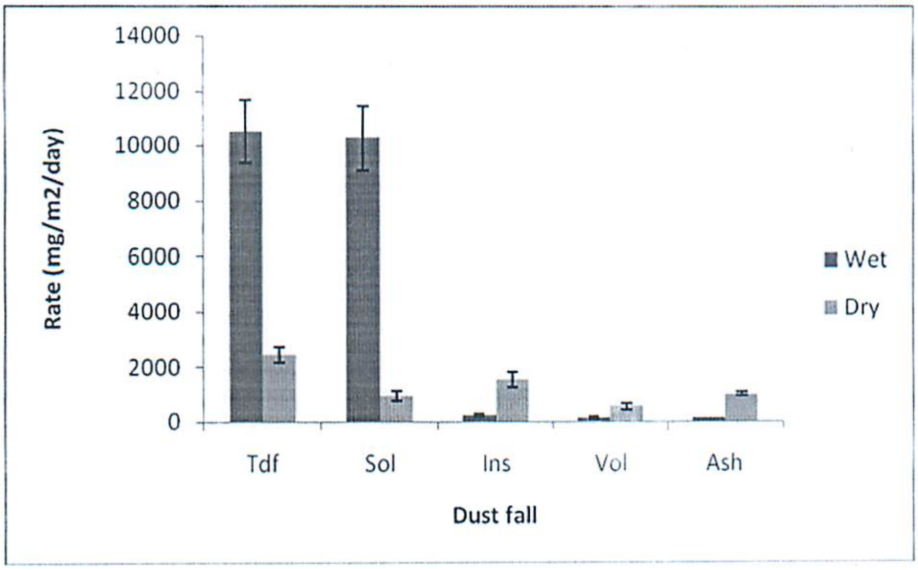

Figure 6: Seasonal Comparison of Total Dust Fall and Components at CI (Tdf = total dust fall, Sol = soluble dust, Ins = insoluble dust, Vol = volatile matter and Ash)

3.6 Influence of Meteorological parameters on Dust Fall Level

Table 4: Meteorological Data

Parameter	Wet Period	Dry Period
Temperature (°C)	28.02 ± 2.18	31.51 ± 1.67
Relative humidity (%)	59.57 ± 11.07	44.02 ± 8.49
Rainfall (mm)	0.73 ± 1.02	0
Wind speed (km/h)	2.04 ± 0.69	1.76 ± 0.7

Table 5: Pearson Correlation Sig (2-tailed) for Comparison of Dust fall, Traffic Density and Rainfall

	Pearson Correlation Coefficient (r)			
Sites	Insoluble/Traffic Density	Insoluble/Rainfall	Soluble/Traffic Density	Soluble/Rainfall
PK1	0.687	-0.018	0.178	0.988
PK2	0.707	-0.432	-0.641	0.991
CI	0.557	-0.757	-0.633	0.978

Correlation is significant at the 0.05 level

The meteorological data supported the discussion so far. There was a lower average temperature (28.02 °C), higher relative humidity (59.57 %) average higher rainfall (0.73 mm) and an average higher wind speed (2.04 km/h) in wet season than their dry season corresponding value as shown in the Table 4. The lower temperature and higher humidity favour the binding of aerosol particles in the atmosphere while the higher rainfall contribute in increasing the washing down of these aerosol particles which are majorly soluble in water in rainy season. Although the wind speed was lower in the dry season, the increase in the level of insoluble dust must have been caused by the hauling movement and traffic activities in the studied sites. Also, increase in temperature, decrease in relative humidity, and decrease in rainfall activities favour the lifting of soil particles into the collecting containers (Manahan (2001), Mkoma et al., (2010), Kamble (2015) and Ifeanyi *et al.*, (2016).

3.7 Pearson Correlation

A Pearson product-moment correlation coefficient was computed to assess the relationship between the levels of insoluble and soluble dust generated with traffic density and rainfalls at various sites. The closer the coefficient (r) to 1, the stronger the relationship while the closer it is to 0, the weaker the relationship. The results are shown in the Table 5. There was a positive correlation for monthly data of insoluble/traffic density at various sites such that increases in traffic density were correlated with increases in the level of insoluble dust at various sites. The relationship was strongest at PK2 ($r = 0.707$), followed by PK1 ($r = 0.687$) and the CI ($r = 0.557$). However, there was a negative correlation for monthly data of insoluble/rainfall at various sites. That is, as either of them increases, the other decreases. The monthly level of soluble dust showed a weak positive correlation (0.178) with traffic density at PK1 while it was negative at PK2 ($r = -0.641$) and CI ($r = -0.633$). Also, level of soluble dust showed a very strong correlation with amount of rainfall at all sites, PK1 ($r = 0.988$), PK2 ($r = 0.991$) and CI ($r = 0.978$). This also suggests that increases in the amount of rainfall correlated with increases in the level of soluble dust fall.

4. Conclusion

This study had observed that the highest total dust fall and soluble dust fall were obtained in the month of September while that of insoluble dust was in the month of January for PK2 and CI while in November for PK1. Also, the rate of soluble dust and total dust deposition decreases from wet season to dry season while that of insoluble dust and ash deposition increases from the wet season to dry season. These variations were observed to be majorly as a result of traffic density and were supported with meteorological data. The observed total dust fall in dry and wet seasons at various sites is more than the recommended 133 mg/m^2/day of Malaysian Department of Environment. It was also above the South African permissible limit (600 – 1200 mg/m^2/day) for dust in heavy commercial and industrial area (SANS 1929, 2005).Therefore, the motor parks ambient air was highly contaminated with soluble dust in the wet season and insoluble dust in the dry season. It is therefore advisable for the University Community and other appropriate authority that have unpaved motor parks all over the nation to take necessary control measurements such as proper paving or regular wetting of the park.

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